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Degeneracy in the Lamellibranchiata.

A Thesis
Presented to the Board of University Studies in the Johns Hopkins University,

For the Degree of Doctor of Philosophy,

By
James L. Kellogg, B.S.

Baltimore,
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[illegible]

Through the kindness of Prof. W. K. [illegible], United States Fish Commission, [illegible] at the laboratory [illegible] of Woods Holl, Mass. Here the work was begun, under the direction of Prof. W. K. Brooks, [illegible] in the [illegible] of the [illegible].

[illegible]

single form may be easily described by the author, but that the comparative anatomy of various forms must be readily demonstrated.

It is interesting to notice in this connection that the great [illegible] of [illegible] in [illegible]-

having such a work as [illegible] Atlas, [illegible] has been of little service. It is a very large volume of [illegible] plates representing dissections; but none of these could have properly described, the mechanism of the organs of special sense, would have been very hard to understand. The use of such a work is also great.

Unfortunately I have been able to obtain very few representatives of this group of Mollusks for examination, and consequently do not feel able to attempt any very wide generalizations. Since the completion of the present work, a full and valuable paper by Pelseneer has appeared, dealing principally with some other forms than those here considered. Much has yet to be done in comparative work in this group, notwithstanding the great work of Lacaze-Duthiers, Wiren, Blumrich and Plate.

The Shell.

The outer covering or shell of [illegible], is made of an organic base impregnated with lime which is taken from the surrounding water. [illegible]

and others have shown that the mantle lobes, bearing the shell valves on their inner faces, secrete a soft, gummy substance, which soon becomes hard, as well as being completely lined with granules of carbonate of lime.

The outer surface of the shell is generally marked by the concentric lines of growth, and along its edge may be found the horn-like cuticle secreted by the mantle edge. This cuticular covering of the outer surface of the shell is often thin and may be lost, especially at the umbo. In the case of Solenomya it is very thick, hiding the entire shell from sight, and extending some distance beyond its natural edge. Internally the valves are white, or colored in various tints. In most cases the coloration is due to pigments in the shell substance, in others to the refraction of light by the prismatic surface. In the former case, where the colors persist, it may fade after the death of the animal, as I have noticed in certain fresh water forms. The shell has sometimes been made the chief or only basis for the classification of the Lamellibranchiata, but a single organ can [illegible]

enough basis for the comparisons needed in mechanics.

Adductor and retractor muscles.

The adductor muscles connect one valve of the shell with the other, and are generally very conspicuous. In order to free the shell, these must be cut away from their connection with it. Each adductor is generally made up of two kinds of fibres, one being of a darker shade than the other. It is well known that the darker portion of the adductor muscle is made up of fibres presenting a striated appearance, which however, does not correspond to the cross striation in muscle fibres of Arthropods and Vertebrates. The lighter part of the adductor is made up of plain unstriated fibres.

This striation of muscle fibres which has been referred to by many writers, has not been described in definite terms but is generally spoken of as an "appearance of striation". As far as I know, it has only been seen in the adductor muscles. I have found in the muscle of the heart of *Ostrea virginiana* a remarkably distinct striation of fibres. I have not yet had the time at my disposal for a careful histological examination of the nature of this striation, though it

-mens it is, for want of specimens for such study, as the stri-
ations are large and not numerous, there being about twenty to [illegible]
of the fibre. The presence of striated fibres as we naturally expect them
in such an organ as the heart where muscular contraction are
involuntary seems surprising. The muscle of the auricle of the heart
almost seems to consist entirely of these striated fibres.

Fig 11, a cross section of a portion of the auricle of the heart in the
Taenia will give some idea of the nature of this structure. [illegible] represents
an apparently homogeneous basement membrane of the newly
ing epithelial wall of the auricle. The striated fibres (m.f.)
run from their attachment to this membrane in toward the centre
of the auricle. They are generally in irregular bundles throughout
in the ones that the fibres are joined to [illegible]. The fibres are very long.

Scattered among these are many single pigment cells (p.g.)
which give the auricle its dark brown color. Also surrounding the fi-
bres are many cells, apparently of an epithelial nature, which seem
to be giving off convoluted ends (?) into irregularly formed chan-
nels thus having much the same appearance as the secreting cells
of the nephridium. Their nature needs further study.

The functions performed by these two portions of the auricle

mentioned above are not well understood. [illegible] thinks that "il est probable que, lorsque les deux parties existent, 'la [illegible] a [illegible] [illegible] [illegible] des adducteurs [illegible] comme plus spécialement destinée à produire des contractions rapides." Although I have made few observations on the subject, I have come to a different conclusion from this. It seems to me that the fibres of the darker portion of the adductor are more compact and firm, and probably supply the greater part of the force required in keeping the shell closed. The fibres of the lighter portion, not being packed so closely together, are able to contract more quickly, and close the shell at any time against a sudden attack. If a valve of Pecten is removed, the smaller, darker area will seem to preserve an extremely contracted condition, while the large white area, also partly contracting, now and then makes sudden and very violent contractions, and then immediately relaxes. These contractions can be caused to occur by striking or touching almost any part of the body. It seems then that a sudden closing of the shell, so often necessary to [illegible], is accomplished by the lighter portion, and that the darker part comes more actively into play when the shell is to be closed for some little time.

the striated portion in *Pecten* is relatively very greatly developed, which, as well as the very large size of the adductor has been brought about possibly by the continuation of its extremely rapid contraction, this being the forced use to the use which produces the function.

The muscle system of *Mytilus* is worthy of record. Fig. 2 represents the musculature dissected out entire. From the base of the byssus, at its anterior portion, two anterior muscle bands, the anterior foot retractors, pass forward, running on either side of the mouth (Fig. 3 a.r.), and are attached to the valves of the shell. They are entirely two pairs very separate muscle bands. The first and all three pairs are inserted in the base of the byssus. The longer side first, with its broad anterior surface, is inserted directly upwards to the shell, as two splendid muscle bundles, which pass behind to the two anterior adductors just mentioned. The foot with these muscles, may be removed without disturbing any of the others, as the byssus organ has lost all connection with the musculature of the foot and the mouth, which it evidently possesses in the very young forms, as have the anterior adductors also.

From the base of the byssus, just behind the insertion of the two anterior retractors extends a great mass of muscle bundles

which attach themselves to the shell above and posteriorly, serve as its means of support. These byssus muscles are arranged in two groups; they are close to one another at the byssus, and diverge laterally as they to become attached to the valves of either side. The anterior extend obliquely backward, and is divided with much regularity into a number of large bundles (Fig. 42, bm).

The Foot

This characteristic organ, appearing generally throughout the Mollusca, is in Lamellibranchs, a muscular projection from the ventral surface of the main body of the animal. It extends more or less anteriorly. In the primitive forms, Nucula and Solenomya, the lower part of the foot is turned nearly forward, and when the organ is greatly hypertrophied, as in Ensis, it arises from the extreme anterior end of the body. In Mya arenaria it is relatively small though functional in locomotion, and extends far forward. [illegible] simple and probably [illegible] [illegible] [illegible] a foot which has a circular ventral disk (Solemya, the Nuculidae and the Solenomyadae). Around the margin of this are a number of thick short papillae. Fig. 52 representing Solemya velum with the right valve and mantle fold removed

show the general relations of the body. It seems to have a volume greater than one-third of the animal, the mantle being very thin. The ventral view is not represented, the figures having been sketched from an alcoholic specimen, but its marginal papillae may be seen. The more usual hatchet-formed foot is that typically shown by *Venus* Fig. 9. It is flattened from side to side, and extends along nearly the entire ventral side of the visceral mass. Its anterior end is plowshare shaped, and is greatly protensile. Instead of being somewhat flat on its ventral surface, it is more or less sharp or keel-like. In *Mya* the foot is much compressed laterally, and is slightly sharper above than below Fig. 11. It does not extend along the ventral side of the body as in *Venus* but occupies a position more like that of *Mytilus* and *Pecten*. In this latter form it is a short, cylindrical projection from the anterior end of the visceral mass. In *Ostrea* and *Anomia*, which are fixed forms, the foot has entirely disappeared.

This organ serves a number of different purposes, but is generally used as a burrowing organ. The forms with a ventral keel are very active. *Solen*, whose [illegible] foot, makes a sharp point of the anterior end of the disc, and rapidly burrows into the

round. The disc is now rapidly expanded, presenting a firm anchor. The foot is then contracted and draws the body down to the end of the foot in this way gradually moving it. Sphaerium have the same habit and also they swim rapidly through the water by means of the peculiar foot as a paddle. It is stretched out anteriorly, the disc formed, and a rapid backward stroke is made. This is repeated with great rapidity. Pecten and other Lamellibranchs move by clapping on the ventral side of the body, but as far as I have observed it is done in a very imperfect way, the animal frequently falling over on its side.

The Byssus.

This organ is generally considered to be a product of the foot. The byssus itself is made of a number of horny matted fibres which are commonly attached themselves to foreign objects. The gland which does the secreting, the byssus organ, assumes various positions in different forms. In Mactra there is a small gland near the posterior edge of the disc of the foot. In Lucina, Tellina a well developed byssus is present in a slight groove near the middle of the ventral surface of the foot. In Mytilus the great byssus organ comes connecting with the foot in the adult, being situated behind it. The byssus organ of Anodonta is one of the best for

relations, for it is not complicated. Fig. 13. represents a horizontal section through it. The secreting surface, f, is highly folded, and in these folds the secretion is seen in deep shade p. Surrounding the folds is a mass of secretion made of concentric layers which have been added to its inner border. At the inner ends of the folds are many vertical muscle fibres, which are strongly inserted, and serve by their attachment to the valves of the shell above, as a very powerful support.

Fig. 14. shows the epithelial surface of one of these folds, the greater number of the lining cells approach to a columnar form and appear to be ciliated. At the deeper part of the fold the lining cells suddenly become large, indistinct and vertical; and I could make out no nuclei in them. The cells which seem from the appearance of the sections to do the secreting are the epithelial cells ep. The byssus secretion, b, I never found extending down over the large clear cells. In some sections the different situation of these cells suggested that possibly there was really a double secretion instead of a single one.

The Mantle.

It is loosely joined to the inner end of the shell. The whole

[illegible] will be seen to be covered by two flapping folds, as in the figures, generally united to one another on the inner dorsal line, and attached to the top or sides of the [illegible] [illegible] laterally. These folds having drawn back over the gills and [illegible]

In many more [illegible], [illegible], [illegible] Trigonia [illegible] and [illegible] the ventral edges are free from one another, and are not in connection with the gills. In [illegible] the mantle folds are not connected with one another ventrally, but are connected with the outer lamellae of the outer gills. In others beneath the ventral borders are fused and are connected with the gills. [illegible] is an exception to this which is that the mantle is fused and is not connected with the gills.

Mya, figures 23 & 24, [illegible], as a good example of the [illegible] continuance of the mantle. In such cases there are left two small posterior apertures or [illegible] away from [illegible] one of the mantle chambers, and a large anterior one for the protrusion of the foot. These three openings are always present in such cases except in [illegible], where there are but two openings, the one for the foot and a single one for both inhalant and exhalant currents of water. This has also been noticed by [illegible] [illegible]

[illegible] portion of the mantle margins in separating the [illegible]. In an old specimen this posterior separation may be seen, when the animal, before it opens its shells after being disturbed, to have the shape of an elongated slit, as represented in Fig. 6, A. As the sides of the slit approach each other, the upper and lower ends become circular and there are formed a lower branchial and an upper cloacal opening, Fig. 6, B.

In Mytilus Figures 53 to 4, the mantle edges lie very close to one another, but are not actually united.

In the oyster Ostrea virginiana, the mantle folds are not united with the visceral mass at all points on both sides. They are in connection on the left side, which lies back in the bottom of the fixed valve, but the right side is [illegible] over the pericardial cavity, and that portion of the visceral mass immediately anterior to it; the mantle is perfectly free from the visceral mass as far ventrally as the [illegible] between and the outer lamella of the outer gill; a [illegible] cavity is thus formed, chiefly over the pericardium. It opens dorsally to the exterior, and its lower portion opens into the epibranchial chamber, which in this region receives water from both gills

It is probable that some of the water coming with the [illegible] inwards through the gill lamellae passes again to the exterior by means of this [illegible] path, instead of going backwards through the epibranchial and cloacal chambers. It possibly [illegible] aids in the aeration of the blood by bathing so much of the mantle wall with water, for the latter is [illegible] supplied with blood spaces in forms like *Unio* and *Anodonta*. What may have caused this asymmetrical condition to appear I am unable to conjecture.

The Siphonal Region of the Mantle.

The posterior parts of the mantle lobes are variously modified to form openings for the inflow and outflow of water. In certain cases where the mantle folds are not fused, though closely [illegible], they are opened apart in two regions close to one another, making an upper and a lower opening, *anal* and *branchial*. These are provided with numerous branched tentacles present also at the ends of the siphons and in *Solen* at their base. (Cooke, Vol. 3, Mollusca, 40).

This represents the region as represented by Fig. 14 in *Mytilus* or is slightly modified as seen in Fig. 17. Here we see that the two separated openings in Solen and *Mytilus* are made

siphons, and that they are [illegible] [illegible], we will [illegible] in the [illegible] the condition in the siphonal [illegible], Fig. 9. A vertical section through this region in Venus, Fig. 10, shows the relations of these parts. Below, is seen the branchial chamber b.c., into which hang the gills g. The upper part of the gills forming the floor of the epibranchial chamber e.c. is seen in section and the opening of the water tubes into the latter chamber are indicated. Separating this above, is the posterior adductor p.a. The epibranchial chamber is continuous with the cloaca cl. and into this the anus, a, opens the rectum r. The cloaca is continuous externally with the anal siphon, and the branchial chamber with the lower branchial siphon. Near the base of this stretches the branchial membrane b.m., a view of this membrane seen from before is given in Fig. 11. It does not extend through from one side to the other, but prevents the upper [illegible] of [illegible] [illegible] extending upward.

One might naturally suppose that from its position this membrane would allow water to enter the branchial chamber, but that any back flow would apply it over the base of the siphon, and prevent the water from escaping

Out of the incurrent to greatly reduce out of the water. The valves close, and the water in the branchial chamber is discharged principally through the branchial siphon, so that the membrane would have been raised in order that this might occur. If the valves of the shell should suddenly close much of the water in the branchial chamber would escape ventrally. While this is going on the siphons are being drawn within the shell and of necessity against this pressure in the branchial chamber, caused by the closing of the shell. If, instead of being closed, the branchial siphon should be opened and thus allow the imprisoned water to rush out it would allow their retraction to be more easily accomplished. The siphons of Unio, however, are small, and do not need the difficulty in retraction encountered by the enormously developed siphons of Mya arenaria, the "long necked clam" especially as the branchial chamber is here closed below over nearly its entire extent, and allows little water to escape between the mantle edges. Perhaps

the siphons are contracted, and the process is always a slow one; a stream of water is discharged from both, but mainly from the branchial. The branchial membrane is not here present, but may perhaps be represented by part of the thickening in the siphonal septum. Fig. 44. If this is so, the organ may have been lost because of its interference with the tedious process of withdrawing the siphons into the shell. What advantage may be derived from the possession of a branchial membrane, is not apparent.

The muscles of the lamellibranchiate siphons may be divided into two chief groups, a transverse and a longitudinal layer. So far as I know there are no circular fibres. Small transverse and longitudinal layers alternate with each other to form the siphon walls. These are beautifully shown in Solen. Fig. 68. represents a transverse section of a bit of the siphon walls of this form, showing the cavity of the anal and ½ that of the branchial

ial siphons. The transverse layers (m.m.) extend across the wall. Nuclei are found most frequently in the central, connective portion. At the outer edges of the layers the fibres separate and spread out to become attached. In this region also, numerous nuclei of the fibres appear. The longitudinal muscles appear principally between the transverse layers, and but there are also many smaller bundles near the point of attachment to the transverse muscles. The whole siphon wall, exterior and inside, is covered by a jellylike tissue containing nuclei, and at places showing elongated cell walls.

The Digestive Tract.

The mouth. This organ is situated in the median line between the two labial palps and just behind the anterior adductor, where it is present. It is not clearly marked off from the oesophagus being a funnel-shaped opening to it.

The palps. These are two lips or folds anterior and posterior to the mouth. They extend laterally

on either side toward the anterior end of the gills. They are of moderate size and triangular ([illegible] and [illegible]). In other cases they may be extended in narrow bands (Mytilus), or they may be short and thick (Ostrea).

Fig. 95 shows the relation of the palps to the mouth, as well as their most usual shape. The figure represents the anterior end of the body of Mytilus cut in a transverse plane just posterior to the mouth. The most posterior or inner palp (ip), extending on either side of the mouth opening, borders the latter, which is situated just above mo. The outer palp (op) occupies a similar position before the mouth. A dense ciliated structure is seen to exist over the lower three fourths of the inner surface of the palp, and the surface of the inner palp opposite to it is similarly thrown into folds.

These folds appear to the unaided eye very much as do the gill filaments, and have the same office to conduct the particles from the gills

They are simply ciliated ridges occurring on but one side of each palp – that next the mouth. Sections across the folds, would differ somewhat in appearance, according to the region from which they were taken. Fig. 12. represents a section across the folds of the palp of Ostrea, in the central region – in this case further away from their attached part of section (Fig. 9). The folds at the free edge of the palp are generally thicker than at the base, and are thrown into two or three small secondary folds. The ciliated epithelium covering the folds, is composed of much elongated cells, more greatly developed on the side of the fold on which occur the secondary folds. The base of the folds rest upon a more or less complete connective tissue layer (ct). The transparent, irregular cells composing the main body of the palp, and extending into the folds, are the same as those found in the connective and walls of the visceral mass of Ostrea, and described by Prof. Brooks (No 3) as fat cells.

Fig. 13. is taken from about the middle of the pulp. Here the folds are more regular, and the numerous secondary folds on the side of the primary folds, have given way to one secondary fold. In Fig. 14, a section close to the attached border of the pulp, the folds are very regular in size, and are without secondary ridges.

The pulps of Pecten are peculiar in having upon their free edges near the mouth, a number of projections which are extremely convoluted, and give the appearance of a heavy fringe. Fig. 15, represents a small portion to show the nature of this fringe. The small figure at the right, represents a single branch, whose base is continuous with the free edge of the pulp, near the mouth. The trunk of this tree-like mass is not solid, but is merely a flat sheet of pulp tissue, whose surface nearest the mouth is concave. The outer surface, shown in the figure, is convex. A section across it would be somewhat crescent shaped. Fig.

C represents a part of the extreme tip of the fringe more highly magnified. Here the anterior side of the mass is presented, and it shows that the whole fringe is made by flaps which arise only on one side of the edge of the palp. The edges of these flat projections turn inward toward the mouth. These edges seem to have grown a great deal more rapidly than the interior of the sheet, and have thus been forced to convolute themselves greatly.

A section through the neck of this fringe, shows an epithelium made up of very much elongated ciliated cells fig. 7C, whose nuclei are arranged in quite a definite row in their outer third. At many points in the epithelium are found groups of large gland cells (gl.). At the base of these cells is a more or less definite basement membrane (bm.). Running through the connective tissue of the fringe are blood vessels, whose flat bounding endothelium is plainly seen (bv.).

The labial palps take their origin upon the

cells from the anterior ends of the latter, and by their cilia, pass it on into the mouth. The movement of the food particles here does not seem so rapid as upon the gills, and its path seems much less defined than upon the latter. This is easily seen upon the palps of Yoldia. The long ciliated appendage of the palp, with its convoluted border, is very similar to the fringe about the mouth of Pecten. The appendage in Nucula, like that of Yoldia, is supposed by Pelseneer (no. 3) to serve in collecting food, and the mouth fringe of Pecten in all probability also has a similar function. The products of its gland cells, cementing the food particles together, as on the gills, and its ciliated epithelium passing this down its concave inner surface to the mouth.

The oesophagus. In the Nuculidae, Stempell (no. 4) has described in the buccal region of the digestive tract a transversely enlarged glandular portion called the pharyngeal cavity. It occurs in no other Lamellibranch, but is homologous with a cavity

found in other Mollusks (Chiton, Fissurella, Haliotis and Dentalium). The oesophagus passes nearly vertically upward to the stomach. It is very long in Solen (Fig. 43 oe), smaller in Mytilus (Fig 53) and Venus (Fig. 1), the opening into the stomach is generally somewhat funnel shaped, but in Pecten is abrupt, with a definite muscular opening.

The stomach. This organ is a greater or less enlargement of the alimentary canal, and is placed in the dorsal part of the visceral mass, frequently in individual cases it lies much more in one side of the visceral mass than in the other. The walls are often very irregular. The liver ducts open into it at various points. The number of ducts varies in different forms.

The intestine. The stomach narrows posteriorly to open into the intestine. In most cases this is coiled. In the degenerate Septibranchia it is almost straight and, according to Pelseneer, is [illegible]. The intestine is but little coiled in Solemya (Fig. 36). The [illegible] is elongated dorso-ventrally, from its position

showing the intestine 2. This proceeds backward and upward, and makes a single loop on the right side. It then proceeds posteriorly over the posterior adductor, and ends at the base of the anal siphon.

The intestine is generally greatly convoluted, and its definite loops and coils are characteristic for different species.

Crystalline style. This organ is a diverticulum of the stomach or intestine. Its epithelium evidently secretes the transparent substance of the style. Fig. 2 represents the developed style of Mya, arising from the lower, posterior end of the stomach, and running ventrally. It ends blindly near the lower end of the visceral mass. In Ensis it is very long and runs down out of the visceral mass into the muscular edge. The style in some bivalves appears to be made up of concentric lamellae. If the large style of Mactra be taken out of the animal, and the end of it carefully teased, we find that it seems to have a central axis, around which lame-

ther are deposited in a concentric spiral. This inter portion may be unwound to any extent from the central axis, showing its spiral arrangement.

The morphological significance of the style is uncertain. Its homology to the [illegible] sac of other Mollusks is uncertain because of the unusual position of the style. Its function is also unknown. It has been supposed to be a reserve of food material, which view I am inclined to accept. Barrois and [illegible] suggest that its purpose is to surround sharp particles in the digestive tract which might injure its lining epithelium. Such a function seems to me improbable. The living cells of mouth and esophagus could hardly not have into the stomach a foreign body much larger than a small grain of sand. Further, [illegible] with the digestive tract only in this way be many of the forms large proportion of sand got into the stomach, and it would be impossible for the style substance to protect the stomach walls from such a mass of foreign mat

by covering them. Now if an extraordinarily large and sharp piece should enter, this function of protecting the stomach must take place — a function which seems altogether improbable.

The Liver

This gland is paired, there being one on each side of the visceral mass, in uniting with the latter however, the dark brown mass surrounding the stomach, gives an appearance of being in two parts. The position of this mass in Unio is shown in Fig. It extends from near the umbo dorsally to the to the extreme bottom of the visceral mass. It occupies nearly the middle of the visceral mass, excepting below, being surrounded by the sexual gland g.

The extent of the liver in Venus is seen by an examination of figures 11, 12, and 13, to be much the same.

Usually the secreting tubules of the liver are closely bunched together. In the more primitive forms however, as Nucula, Yoldia and Solemya, the liver seems as not at all compact. In Yoldia the

liver lobes, surrounded by the sexual gland, are often found scattered throughout most of the extent of the gland, being only connected by long branching threads of a connective tissue.

The Generative Mass.

The greater part of the visceral mass is made up of this organ and the liver. It is of a much lighter color than the latter gland, and varies much in its external appearance in different forms. It is a large gland, surrounding the liver and constitutes the posterior part of the visceral mass. In Pecten, it reaches the body walls anteriorly, surrounds the liver, and closely invests the intestine throughout almost its entire extent. A part of the visceral mass extends down beneath the pericardium, and backward for some distance beyond the adductor muscle, where it ends in a blunt, rounded point forming part of the anterior boundary of the cloacal chamber. The intestine extends almost to the extreme

This and then returns toward the stomach. Also in this region found entirely surrounded by the genital gland, which is also seen at the posterior end of the body, represented in Fig. 1 g. In the region also, the visceral mass extends in much the same way above the pericardium, and over part of the adductor. It consists here of the rectal part of the intestine, surrounded by a layer of the generative gland, which becomes thinner and thinner until it finally disappears a short distance from the end of the rectum. This is seen in sections above the heart region at g. Figures 4, 5, 6 and 7. In Venus the generative gland penetrates the uppermost muscles of the foot as is usual in forms in which locomotion is performed by this organ. In the case of Solen, where the organs of the visceral mass are not at all crowded, the genital gland still occupies a considerable part of the base of the foot. The boundaries of the gland in [illegible] may be seen in Figures 24 & 25.

In Anomia, greatly modified in many ways on account of its fixed condition, the sexual gland is very unsymmetrical, extending out into the mantle on the right side. In Mytilus the foot is entirely muscular and contains none of the sexual glands. Very much of the visceral mass, also, is occupied by the large byssus muscles, and as a result, the generative gland has pushed out into the mantle lobes of both sides, and completely fills them. (Figs. 32 & 4).

In the majority of cases the sexes are separate, but hermaphroditism exists in many cases here and there throughout the group. Pelseneer, after enumerating some of these cases says "Dans tous ces animaux la glande génitale elle-même est hermaphrodite; elle produit donc toute deux éléments les oeufs et les spermatozoïdes, ou bien il y a une partie est spécialisée pour donner naissance à chacun de ces produits, ceux-ci sont évacués au dehors par un seul canal."

hermaphrodite "*Aplysia*." In *Aeolis* both glands are united to the liver, the testis being the inner portion of the two. The ovary is of a saccular type, which is very marked in the live animal.

Fig 7. represents a section passing vertically through the outer wall of the visceral mass, where the testis and ovary are apposed to one another. The body wall is represented at *e.p.*, and consists of a single layer of columnar cells whose nuclei are almost equally distant from their ends, and the thick basement membrane. The follicles of the ovary *f.*, are not so regular in outline when seen in section as those of the testis. The walls of the latter have a follicular epithelium *f.e.* In the ovary, the cells in this layer are in all stages of development into eggs. The eggs themselves, occupying the follicles, possess a very thick egg membrane, and the protoplasm is finely granular. A duct from the follicle is seen at *d.*

The mother cells of the spermatozoa (fig) are circular and of considerable size in the follicles of the testis. We can follow the course of subdivision from these mother cells. They become very gradually smaller and smaller until finally their division results in the spermatozoa. These are so arranged that their "tails" in forming, project in extended masses toward the lumen of the follicle, and give it a radiating appearance. I have not been able to determine how many times a mother cell divides in forming spermatozoa, for the cells are all rounded, and give no evidence of their divisions, as they do in the testis of many animals. The ducts of both testis and ovary are composed of slightly columnar, ciliated cells. In the mother sperm cells of *Mytilus* the chromatin is arranged in a crescent shaped mass at one side of the nucleus. The division of these cells must be same as in the case of *Pecten*.

The Vascular System.

The heart, the chief organ of the circulatory system, is, in the majority of cases, situated in the dorsal part of the body, and is generally elongated from before backward. It consists of a muscular ventricle, and two lateral, usually more delicate, auricles, opening into it, one on either side. The organ lies in an extensive pericardium. The usual relations in position between these parts, may be seen in Fig. 45. In a few cases, as in the oyster, the heart has changed from the usual position until its long axis is dorso-ventral.

As a rule the ventricle of the heart is traversed by the rectum. Its position in the ventricle of Pecten is shown in Fig. 45.

In most cases the heart gives off an anterior aorta, which runs forward above the rectum and a posterior vessel proceeding below it. In some forms, however, the posterior aorta does

not appear, with one exception in Solenomya, one of the most primitive forms.

It has been claimed that the possession of two aortae was the primitive condition, and that where the posterior one was absent it had degenerated and disappeared. As the general relations of such a form as Solenomya have become known, they have shown that it is probably a primitive form, and as it possesses but one aorta, that condition may have been the original one in the group. In the Gasteropods there is no posterior aorta, one branch of the anterior vessel supplies the posterior tissues of the body. The remaining groups of the Mollusca have both anterior and posterior aortae.

As has been said, the oyster possesses both anterior and posterior aortae. The former comes from the upper end of the ventricle and runs forward to the visceral mass and mantle. The

[illegible] takes its origin slightly posterior to the heart very close to the extreme anterior end of the ventricle, and runs directly backward beneath the rectum, and in the upper wall of the pericardial chamber. Upon reaching the adductor muscle it runs downward running along its anterior surface to a little below its middle, and then penetrates its tissue, and becomes distributed among the fibres.

The oyster probably comes in its degeneration through a form with an anterior and posterior aorta. But in this case the posterior aorta must have shifted its position from the posterior end of the ventricle to its anterior dorsal end.

Arteries break up, not into capillaries but into irregular blood spaces in all tissues of the body which they penetrate. In the gill filaments however, these channels are of a more regular size, and in many cases (Peters, Fig. 83) are seen to be lined with a distinct endothelium.

The blood of Lamellibranchs is colorless with a few exceptions, and contains many nucleated bodies. The Arca and Solen have corpuscles containing haemoglobin, so that the blood is distinctly red.

The relative amount of blood is very great in active locomotor forms, where it is used in protruding the foot, and in such sedentary forms as Ostrea and Mytilus is comparatively small.

The path of the blood through the gill filaments is not known, and would be impossible to determine in those forms in which the gills have become greatly complicated, on account of the colorless condition of the blood especially, since the movement in the filaments cannot be followed.

It seems altogether probable that the course of the circulation in the gills is very dissimilar in different groups of lamellibranchs. In those forms in which the gills are made up of a series of leaf-like plates (Nucula, Yoldia and Solenomya)

path is then a little more than a blood sinus, where outer edge a blood channel is more distinctly marked out. While a circulation may be more or less distinct here, it cannot be properly said to be formed with a descending and ascending fluid in the filaments, and when the latter is not united with the mantle or neighboring filaments, the blood cannot flow out to the extremity of the filament, and then back again, perhaps however, not always taking exactly the same path back. It will be noticed that, in gills of this kind, the blood spaces of the filament are divided by a septum, if the filaments are greatly flattened out. This latter condition is found in *Arca pexata*.

The blood corpuscles of *Arca* are colored by haemoglobin, and I have attempted to trace the circulation in the filaments. I removed one valve of the shell, placed the animal in water, and examined the gill by separating without injury a few filaments at a time, so that one

connected with one another only by the ciliated junctions on their sides. Under the microscope the pale-yellow corpuscles could be seen circulating in the blood stream. In both outer and inner lamellae, the current would keep up a uniform flow outward for half a minute at times, though the rate of the current did not remain constant. The stream would become slower, finally stop, and then a backflow would set in. After a short time this ceased, and the current resumed its original course. I did not make out any separate currents, but could see individual corpuscles being carried in one direction, and then back in the other. The currents in the different filaments were independent of one another.

In cases where filaments are joined to the mantle and the ventral side of the visceral mass, *Mytilus*) the blood may be finally collected in vessels running along the base of the con[illegible]. The currents through the filaments

cannot be at all definite, as the filaments join with one another at various places.

It seems probable that the gill is used as a respiratory organ in all lamellibranchs, though in others very little blood apparently gets into them. In some cases, the other surfaces of the body, and particularly those of the mantle, may play a more important part than the gills, in the aeration of the blood.

The Excretory Organ.

The nephridium is situated immediately beneath the pericardial chamber. The more primitive condition of the gland is preserved in Nucula, where it is a simple tube, bent upon itself. One end of this opens into the pericardium, the other to the exterior by the branchial chamber. The lining epithelium in these cases is similar in all parts of the tube, and is all secretory. It consists of large, cubical, vacuolated cells, without cilia. The generative glands open into this kidney, and also the pericard-

dual opening. there are two secretory organs, one on each side with no connection.

There are many variations from this simple type, but the general plan is always followed. In most cases the duct becomes differentiated so that its terminal half becomes non-glandular, while only the half [illegible] with the [illegible] becomes glandular. An account of this duct in the gland. The glandular portion is [illegible], and the non-glandular [illegible] in vertical section.

The position of the organ in [illegible] is [illegible] 17. It [illegible] and [illegible] under the [illegible] and it extends backward [illegible]. The [illegible] as far as the [illegible] between the light and dark muscle fibres. It is thus seen as in [illegible]. To [illegible] a great part of its [illegible] directly to the [illegible] in the [illegible]. The glands of either side are entirely separate from one another. The secretory portion of the gland gives off a great number of branch-

ing diverticula, lined by an secretory epithelium.

A portion of one of these diverticula is represented in Fig. 14. The lining cells are columnar, and rest upon a thick basement membrane. The protoplasm is mostly collected at the base of the cells. The distal ends contain a large, watery vacuole, which is finally discharged into the lumen of the tube. Many of these vacuoles contain a small, rounded particle which stains deeply, and which may be of a excretory nature. Secretion, as commonly found in the glands, however, seems to be entirely wanting here. The products discharged into the lumen are undoubtedly liquid, for by teasing in the ovary, when fresh cells are used, they may be easily seen to run into one another, and form larger masses. None of these cells give evidence of ciliation.

Figures 15 and 16 represent sections from the secretory cells of the kidney of Helix.

These are sometimes very large, and their concentric structure is readily seen. Figures 56 and 57, are from macerated preparations. The former shows a small nucleus n, and the concretion in the distal portion of the cell con. The concretions form a more dense, highly staining central portion, of various shapes and sizes. Scattered through the cell substance are many small, vacuole-like bodies v, probably the first appearance of the secretory products in fluid form, which afterward construct the solid concretion. Other cells (Fig. 58) of a more elongated shape, appear to contain only watery vacuoles vac.

[illegible] has shown that the sexual glands of Pecten opened into the kidney. In examining the nephridia of this form in the spring and early summer, I have almost always found that they contained eggs in various stages of development, often in very great numbers.

They are, in all probability, the eggs of the individual examined, which have lodged in the kidney instead of being thrown out to the exterior, and not eggs from some other animal taken in with the surrounding water. In this case they have probably become fertilized from spermatozoa taken into the kidney from the exterior, having come from another individual, if it is always true that the male elements in these hermaphrodite forms are always ripe before the female as observation seems to indicate.

It thus happens that the spacious kidney of Lottia becomes a brood pouch for the young, since I have seen a kidney containing great numbers of active ciliate larval forms, which it seems probable, both on account of their number and the connection between kidney and genital gland, developed there from the egg. It is true that this arrangement may be a purely accidental one, but I was inclined to believe that the arrange-

age gained is considerable, and as in many instances are protected for so long a time, the kidney may, by the operation of natural selection, have become especially adapted for this function.

The Nervous System.

Of the three pairs of ganglia, the cerebral are generally situated near the sides of the mouth, and are joined by a supra-oesophageal commissure. They are generally closer to each other in the more primitive forms. The visceral ganglia, generally placed on the ventral side of the posterior adductor, occupy in Nucula and Solenomya a position in front of it, connected with the pedal ganglia in the foot. Otocysts, as these lie on the surface of the latter, are probably always innervated from the cerebral ganglia. The [illegible] may be seen near the tongue sometimes a single otolith; in others, there may be several small particles.

In three of the groups of Lucina there are gen-

tension, the cell walls of which could not be distinguished. Nuclei of different shapes and sizes lie scattered about through it with great irregularity. These cells can appear a dense supporting membrane, and the whole is enveloped in a capsule having a fibrous appearance. There is but a single large otolith, whose concentric structure is very evident. There is also, in the cavity of the otocyst, what appears to be a coagulated fluid.

The ciliated epithelium as far as I was able to see, possessed no trace of cilia. This apparent absence of cilia has also been described for the otocyst of [illegible] by [illegible] (No. [illegible]).

The Gill.

The gills of [illegible], like its foot, [illegible] [illegible] [illegible] [illegible]. They are represented by Fig. [illegible] (Plate [illegible]). The [illegible]

opening; consequently, seeing the track of the posterior adductor. From thence it proceeds forward in a curved line near the top of the pericardium [illegible] and over the anterior adductor.

The free edge of the left mantle lobe may be [illegible] ber is thus formed, the upper boundary of which is the line of attachment between mantle and [illegible] gy, and below is suspended the four, the gills of [illegible] same distance on the posterior side. In Section [illegible] the outer adductor muscle and visceral mass. In Ostrea, each of the four gills is connected above with the one next to it, and the outer ones are also connected with the mantle. A vertical section Fig. 2 shows each gill to be [illegible]

[illegible]

are united to each other across the top of the visceral mass, and, to the top of the outer lamellae of the body; and in the median line, the apparent inner lamellae. In Fig. 2, which is a section near the anterior end of the gills, they are also [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] seen in all figures of crosssections of this form.

By this union of the gills above, the mantle chamber being so completely shut off from all the spaces which appear in section above them. [illegible] [illegible] [illegible] Fig. 6, form [illegible]

The gill lamellae are made of numerous parallel filaments [illegible] are in [illegible] into the branchial chamber. This current is mainly by the ciliated cells of the filaments. The spaces between the lamellae are called water tubes. The [illegible] (Fig. [illegible]) [illegible] Figures 13 and 14.

The [illegible] present, situated on the ventral side of the visceral [illegible] Fig. 14. The [illegible]

[illegible] separate the [illegible]. The right and left [illegible] [illegible] of that cavity will be seen inside the [illegible] sac. Behind the visceral mass and [illegible], the [illegible] [illegible] join each other, forming a [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] to the [illegible]. [illegible], [illegible] [illegible] a complete separation between the cloaca and branchial chamber (Fig. 93).

[illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible]. The [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of the body, further back into two; and finally [illegible] [illegible] the cloaca.

b. [illegible] [illegible] [illegible] [illegible] [illegible] branchial [illegible]. For as may be seen in Figures 92 to 94, the inner [illegible] of the gill- [illegible] [illegible] to the body wall nor is the [illegible] [illegible] [illegible] with the [illegible] as they are in the [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] directly into the [illegible]-

[illegible] character, and [illegible] their [illegible]-ments. The [illegible] [illegible] [illegible] [illegible] to the [illegible] of the [illegible] [illegible] [illegible] by a [illegible] [illegible] [illegible] [illegible] (Fig. 7).

Lamellibranch gills. The gills of the [illegible] [illegible] [illegible] [illegible] [illegible] for the great majority of Lamellibranchs. The gills of a few primitive genera (Nucula, Yoldia and Solenomya), however, are entirely different in appearance. They were first made known by Pel-seneer (Fig. 8). [illegible] of [illegible] [illegible] consists of a series of flat plates [illegible] [illegible] [illegible] and [illegible] [illegible] by a [illegible] [illegible] [illegible], [illegible] is [illegible] [illegible] the [illegible] [illegible] on the [illegible] of the [illegible] mass. The palps in Nucula and Yoldia are very large, and extend back for some distance within the visceral mass. The gills, posterior to them, are attached to the base of the siphons.

Fig. 42 represents [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] the right. The figure [illegible] [illegible] [illegible] plate or two plates, one on each side. The supporting [illegible] [illegible], are the ventral [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] is a groove, [illegible] [illegible] shown in the figure, separating the plates of either side. Other evidence will be given to show that these plates are really separate and that one plate does not extend entirely across the [illegible].

[illegible] [illegible] (Fig. [illegible]) [illegible] [illegible] [illegible] [illegible] (Fig. [illegible]). The [illegible] [illegible] is attached to the [illegible] [illegible] by a short [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] on the side of the body instead of [illegible] from below the point of the attachment of the [illegible] [illegible] in [illegible]. The [illegible] of the [illegible] [illegible] single [illegible] [illegible]. The

[illegible]

[illegible]

length of the animal, from the [illegible] adduc-
tor adductor, back to the siphonal septum,
and separating the [illegible]
side of the body into an upper and a lower
[illegible]. Through this [illegible]
ber of orifices of [illegible]
[illegible]
[illegible] with the upper chamber. [illegible]
[illegible]
water obtained from the [illegible] being
[illegible] through the [illegible]

[illegible]

[illegible]

account. The relationships which they [illegible] exist among the various [illegible]. The [illegible] have been thoroughly studied in a [illegible] way. The work of [illegible], such as [illegible], were [illegible] [illegible] [illegible] [illegible], who first made [illegible] [illegible] [illegible] Maimonides, was the first to [illegible] his views, and he gave a theory of the [illegible] the will, which is generally accepted as [illegible] the one. There are, however, [illegible] [illegible]

The gift of [illegible].

If a divine [illegible]

which may be examined in sea water. The gills may be seen to possess a different color; the thickened [illegible] edges of the plates being [illegible] [illegible], and the thinner distal edges are of a [illegible] [illegible]. The gills will be observed to be able to contract themselves in a variety of ways; in the first place they may shorten themselves to a [illegible] [illegible] [illegible], and [illegible] the [illegible] of the plates [illegible] more completely. In the second place [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

Still another mode of contraction may often be noticed [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] a certain region of its surface [illegible] forward or backward, so as to [illegible]

[illegible] engaging tissues. The neighbouring joints, [illegible] being closer to the joint on the other side — either [illegible] [illegible] joints [illegible] [illegible] the remaining joints [illegible] [illegible] These levers may run either forward or backward, [illegible] [illegible]ility.

[illegible] of the [illegible] [illegible] the [illegible] [illegible] in the [illegible] [illegible] the case of Levers [illegible] [illegible] of the [illegible] [illegible] [illegible] in the [illegible] [illegible] the [illegible]

central cavity of the cell, into which they are thrown. On the way to this cavity, they have evidently become covered by a [illegible] of [illegible] for the [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]. The [illegible] [illegible] [illegible] [illegible] and [illegible] [illegible] with the surface of the pulp.

The [illegible] of [illegible] [illegible] through the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of the [illegible] [illegible], Fig. 7. [illegible] a section [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] e see Fig. 8.

The [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] of the [illegible] [illegible] [illegible] [illegible] [illegible] for [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] edges of the cell [illegible] of [illegible] [illegible]. This portion of the cell is [illegible] and [illegible].

[illegible]

[illegible] the middle [illegible] extent [illegible] the [illegible] place [illegible] [illegible].

[illegible] [illegible] sphere [illegible] [illegible] [illegible] [illegible] on the [illegible] [illegible] possibility of approaching [illegible] [illegible] the application [illegible] [illegible] upon [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

The [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] of the [illegible]. [illegible] [illegible] [illegible] [illegible] of [illegible] the [illegible].

The [illegible] [illegible] connected with [illegible] [illegible] [illegible] [illegible] [illegible]

Fig. 2. represents a section cut horizontally through the gill lobules of one side in a plane indicated by the line z in Fig. [illegible] [illegible] This region where the [illegible] [illegible] [illegible] [illegible] arrangement appears. The outer edge of each plate is rounded and composed of short columnar cells bearing very short fine cilia on the external side [illegible] surface [illegible] on the lateral sides of the rounded edges are [illegible] rows of cilia interlocking closely with [illegible]. The [illegible] these ciliated cells on the edges of the plates have been [illegible] [illegible] [illegible] [illegible]. The [illegible] [illegible] [illegible] [illegible] [illegible] though less convoluted. In this section, a portion of the supporting membrane of the gills has been [illegible] [illegible] [illegible] [illegible] [illegible] and many of the cells bear thick spines [illegible] of cilia. The inner part of the section [illegible] [illegible] [illegible] [illegible].

Next the points of one side of the gill structure

are seen continuous with those of the opposite side, as viewed from a section passing horizontally [illegible] in the plane indicated by a, Fig. 41. Such a section is represented in Fig. 40. When the greater [illegible] come together from either side in the median line, they [illegible] [illegible] [illegible] [illegible] [illegible] position in macula. The space a represents the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ing horizontal membrane above. As regards them [illegible] [illegible] [illegible] for purposes of [illegible]. They are shown in Figures 41 and 42. They are always [illegible] [illegible] [illegible] [illegible].

[illegible] than [illegible] muscles, and the [illegible] bringing about the [illegible] functions described above as taking place in the [illegible] The [illegible]

The power of [illegible]

[illegible] of the [illegible]

[illegible] chitinous [illegible], Fig. 11, [illegible] the [illegible]

[illegible]

[illegible] connection is not pressing upon their

[illegible]

[illegible] of protoplasm, the outer edge of which

is deeply stained, and each cell has [illegible]

[illegible]. The size of all cells of the edge are of the

[illegible]

ventral border, where they are [illegible] smaller,

at the lateral edges of the ventral border — and

in the mid line of the ventral surface — upon

[illegible]

[illegible]

[illegible] is,

[illegible]

section of such plate, in the region of the [illegible]

cells, which are larger than the others, each

has a large [illegible]. These are probably [illegible] to

[illegible]

[illegible] as widely found among Annelid [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] nucleus, and appears to [illegible]

a large cell with long cilia, all of which he figures.

The epithelium of the walls of the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible]

Sections show no indications of the folding of the walls, and I have seen no trace of the [illegible] the plates of [illegible].

The [illegible] of [illegible].

If an entire [illegible] of the [illegible] of this form be inverted, it will seem to be made of a [illegible] Fig. 5[illegible], The upper end of the [illegible]

in the filaments, from which proceed the muscular portion of the median septum in Mytilus [illegible] filaments are quite [illegible]

[illegible]

[illegible]

about half their extent — the ventral half — but are connected by the continuation of their inner walls.

There are no vascular connections between the filaments [illegible] fig. [illegible] in a view of the anterior wall posterior face [illegible] the filaments throughout its entire extent.

Fig. [illegible] shows the filaments [illegible] [illegible] elongated cells of the ciliated epithelium are [illegible] ciliated, and extend [illegible]

[illegible], the cells gradually increasing in [illegible] as to the cells which bear them. At a corresponding point on either side, there are three or four cells [illegible] sections, which are [illegible] them [illegible] being distinct. These are [illegible] of cells [illegible] these sections. They extend the whole length of the filament without any break, [illegible] to join [illegible]. They are [illegible] like the entirely [illegible] cells are Heterocysts, [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible] the filament.

The [illegible] growth of the filament is [illegible] of [illegible], [illegible] are [illegible] [illegible]. There are [illegible] of [illegible] [illegible] the [illegible] [illegible] its length. The [illegible] of these [illegible] are the [illegible] the [illegible]

seen by a high magnification, sometimes detached together, or more often from one another. The cilia of these particular cells are very fine ones, the characteristic moving in one direction, and [illegible] have separated from [illegible].

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] nine cells each.

There is probably a continuous vascular space between these walls, though in section they are, as in Solenomya, closely applied to one another, here and there XX, this space [illegible] [illegible] [illegible].

[illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible]

and since are thrown with definite form [illegible] that their surface may be increased to facilitate the aeration of the blood, or the procuring of food, or both.

[illegible] appears in the [illegible] of the gills of [illegible] (Fig. [illegible]). The filaments [illegible] the way [illegible]. The filaments [illegible] [illegible] the [illegible] margin of the [illegible] [illegible] of the [illegible] in the [illegible] [illegible] ([illegible]), [illegible] [illegible]. The filaments at the [illegible] angle of the [illegible] [illegible] Tectum [illegible] is greatly enlarged, [illegible] modified.

Fig. 6, represents a section passing through an entire [illegible] of the [illegible]. This form is [illegible] of [illegible] [illegible] the [illegible] at the [illegible] angle. The [illegible] [illegible] [illegible] [illegible]. The [illegible] [illegible] The [illegible] [illegible] [illegible] [illegible] the [illegible]

[illegible] the opposite side.

The filaments of the [illegible] (fig. [illegible] is much enlarged (see). The filaments [illegible] [illegible] the [illegible] [illegible] cells [illegible], and the [illegible] [illegible] [illegible] [illegible] appearance. The [illegible] [illegible] [illegible] together [illegible] their entire extent, by a continuation of their [illegible] which thus [illegible] the [illegible] space of the gill [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

The [illegible] [illegible] as far as I have yet seen in Pecten. These do not occur on the sides of the filaments as in the Arca, but upon ciliated projections [illegible]

Transverse segments. These are [illegible]

[illegible]

[illegible]

[illegible]

such as dilated spurs or protrude abruptly

[illegible] between the [illegible] of the

gill.

A section passing transversely through the

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Sea anemone [illegible].

Life of [illegible] [illegible].

This animal [illegible] [illegible], more specialized than that of Actinia. The segments [illegible]

[illegible]

and there to allow water to enter into the [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

not entering simple sac into its secondary folds. There is no connection between the [illegible]

[illegible]

[illegible] organ there is a partition between [illegible] consisting of [illegible] [illegible] of [illegible] [illegible]. [illegible] There exists a [illegible] channel [illegible], From these channels there is [illegible] [illegible] [illegible] the water [illegible] on either side of the partition [illegible] [illegible] [illegible]. [illegible] are often [illegible] [illegible]

completely fill the space between the [illegible].

[illegible] these [illegible] appear [illegible]

[illegible]

[illegible]

entirely fill the water tubes, in regions where

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

is made up for the diminished aeration in the [illegible] filaments, Though they sometimes occur within the water tubes, their thin walls are surrounded by water on all sides [illegible] sufficient for the purpose. [illegible] The [illegible] aeration is [illegible] accomplished in [illegible]

[illegible]

The end of this degenerate tube is generally the most complex in the group, the [illegible]

[illegible]

in the thick cross partitions, the ligaments rarely [illegible]

[illegible]

[illegible] edges. This is the case with all the lig-[illegible]

[illegible]

[illegible] space of the fold is a blood sinus, with [illegible]

[illegible] continuous. Very [illegible]

[illegible]

[illegible] into the water tube of the kidney.

[illegible]

[illegible] are slightly thickened at a short distance from the outer edge, there is [illegible]

[illegible]

In the [illegible], certain cells crowd together a little distance removed from the spindle cells, [illegible]

The [illegible]

The [illegible] are broadened and [illegible] distances [illegible]

[illegible]

[illegible] direction.

In our discussion we proceed to the gills.

1. The epithelium of the ventral edges of the gill plates, in forms like Nucula and Yoldia, [illegible] Lamellibranchs is specialized by the possession of chitin, large ciliated cells, and gland [illegible] all forms in which gills are presumably used, [illegible] for the gathering of food, [illegible] nutrition. However large the palps may be, they are certainly not sufficient in Yoldia to [illegible] in collecting food. Besides Yoldia, which I have observed, this function is evident in the [illegible] from the presence of mucus cells and [illegible]

4. The [illegible] of [illegible] cells are [illegible] typified in [illegible] the [illegible] oblique cells [illegible] of Epidermis, are very [illegible] the [illegible] with the [illegible] of [illegible] [illegible] [illegible] a row of [illegible] [illegible] cells, [illegible] the cells, [illegible] [illegible] tinguish them from the oblique [illegible] cells. The [illegible] is shown [illegible] [illegible].

[illegible] ing currents of water & so.

5. [illegible] cells were [illegible] the [illegible]

[illegible]

a [illegible] on either side. The [illegible] neither in Yoldia, though I believe [illegible] [illegible] [illegible] there are the [illegible] of these forms and the [illegible] [illegible] [illegible] [illegible] [illegible] connected with considerable masses on the gill of the living animal, confirms this belief.

In some instances, gland cells occur on the [illegible] edge of the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] very much more so than on the outer edge.

It I believe they are [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the chitinous [illegible], will be [illegible] in the vicinity or [illegible] of the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Yoldia, Pecten, Neritina, [illegible], [illegible] [illegible] [illegible] [illegible] and [illegible].

Fœtal Circulation

[illegible] [illegible] [illegible] [illegible] of the [illegible] the [illegible]

It has been demonstrated that the entire [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] which are supposed to [illegible] [illegible] [illegible] [illegible], [illegible] the [illegible] [illegible] the [illegible] [illegible] the [illegible] all the blood [illegible] [illegible] the [illegible] [illegible] to the [illegible]. The supply [illegible] to the heart at this time from the ventricle. During this process, the [illegible] of the [illegible] [illegible] closed, and the blood is confined to the [illegible], which it returns.

If the animal [illegible] to [illegible] the [illegible] [illegible] the [illegible] of the [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] the [illegible] of the [illegible] [illegible] [illegible] of the [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible]

of the fig., it [illegible] the [illegible]

[illegible] and [illegible] the [illegible]

the [illegible], [illegible] thence [illegible] the [illegible],

[illegible], and then [illegible] the very [illegible]

the portion one-sixth the [illegible].

As has been said, *Ustrea* has so far, the [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] of its great three spaces, which

[illegible]

[illegible]

[illegible]

[illegible] and other forms, by the [illegible]

spaces, and its [illegible] has [illegible]

[illegible]

[illegible]

[illegible]

[illegible] the [illegible]

a united portion of the inner than the [illegible]

The anterior or uterine part; and a thick muscle

a fully developed muscular part, and a

of running by opening and shutting the [illegible]

valves — and as has been preserved in the

This shows how the [illegible] of [illegible], the

suggest the suspicion that the [illegible] [illegible] has been removed by the degeneration of a few [illegible] by a [illegible] accident.

The natural position of [illegible].

It will be noticed from the figures that the cranial case is relatively small, and that a large part of it is filled by the great [illegible] [illegible].

When the fossil skull was [illegible], the [illegible] the cranial case itself by means of a [illegible]. These muscles were probably [illegible] to prevent a [illegible] of the delicate tissues when the animal was subjected to the [illegible] of the waves. The injury would have [illegible] [illegible] if there had been no [illegible] to the [illegible] to serve attachment [illegible] to the [illegible].

Thus the great [illegible] muscles were developed and having been brought out for the [illegible] of such a [illegible] of muscle tissue on the [illegible] [illegible], it was necessary for the [illegible]

pears to find another position, or a decrease in its size would tend to the extermination of the species. As we have already seen, in the [illegible] [illegible] the disappearance of [illegible] [illegible] [illegible] [illegible] [illegible] accompanying atrophy of the body, which con[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] before the [illegible] [illegible] the [illegible].

Conclusions [illegible] a [illegible] [illegible] the Branchial [illegible]

The series of figures representing cross sections shows us the variations in size and conditions of the branchial chamber in the different forms.

The [illegible] [illegible] [illegible] [illegible] the characteristic of those forms which are non-active, or [illegible], [illegible] active [illegible]. [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] to the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] of the body [illegible] [illegible] [illegible] the [illegible] of the [illegible] [illegible]. The [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] and the [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] for the [illegible] [illegible] [illegible] [illegible].

The following [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] with a fully [illegible] [illegible] [illegible]. The [illegible] of the [illegible]

[illegible]
being and acidities in the secretion. The [illegible]
Subsequently we find the [illegible]
[illegible]

[illegible]

[illegible] present in the mouth. But when the animal
[illegible] in the [illegible]
[illegible]
is constantly running into the mouth

[illegible]

[illegible] [illegible], and the animal with its rudimentary [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] in size.

The oyster has become fixed by a valve of its shell and possesses no byssus. The mantle [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of the mantle. [illegible] [illegible] [illegible], the need of the aeration of the blood is very

[illegible] is not [illegible] as a [illegible]. [illegible] [illegible] character of [illegible]; [illegible] the [illegible] The character is recognized by the [illegible].

It is possible that the [illegible], in its [illegible] [illegible] and then a [illegible] on the way to the [illegible] [illegible].

[illegible] the chief one, [illegible] however the [illegible] its [illegible]

structure which amounts to a mere [illegible] [illegible] for the [illegible], these [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible].

One of these is the system of [illegible] which is highly subject to variation from [illegible] modification, as is the [illegible]. Whether it is [illegible] [illegible] it seems as if it were hardly possible to use it as a basis of classification for the whole group, as [illegible] has attempted it, for a group whose [illegible] [illegible] [illegible] [illegible] be subject to [illegible] modification. That there [illegible] [illegible] [illegible] [illegible] of [illegible] of [illegible], and that of a single one; and even a complete knowledge of the comparative anatomy which we do not [illegible] could hardly be used as a basis for classification without the aid of comparative [illegible] which is still less known than the comparative anatomy.

[illegible] The gill.

[illegible] that the [illegible] of these [illegible] which possess plate gills [illegible] that they must be the most primitive forms of the group. [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] but which shows signs of an ascending limb. The next stage is represented by the gill of Arca, in which there is a fully formed ascending limb. The fil- [illegible]

than cylindrical. But right here is the gap, and it would still remain very great, even if this [illegible] [illegible] apart. The absence of [illegible] [illegible] [illegible] of the [illegible] [illegible] [illegible] [illegible] the mathematical theory of these phenomena [illegible] the ascending [illegible].

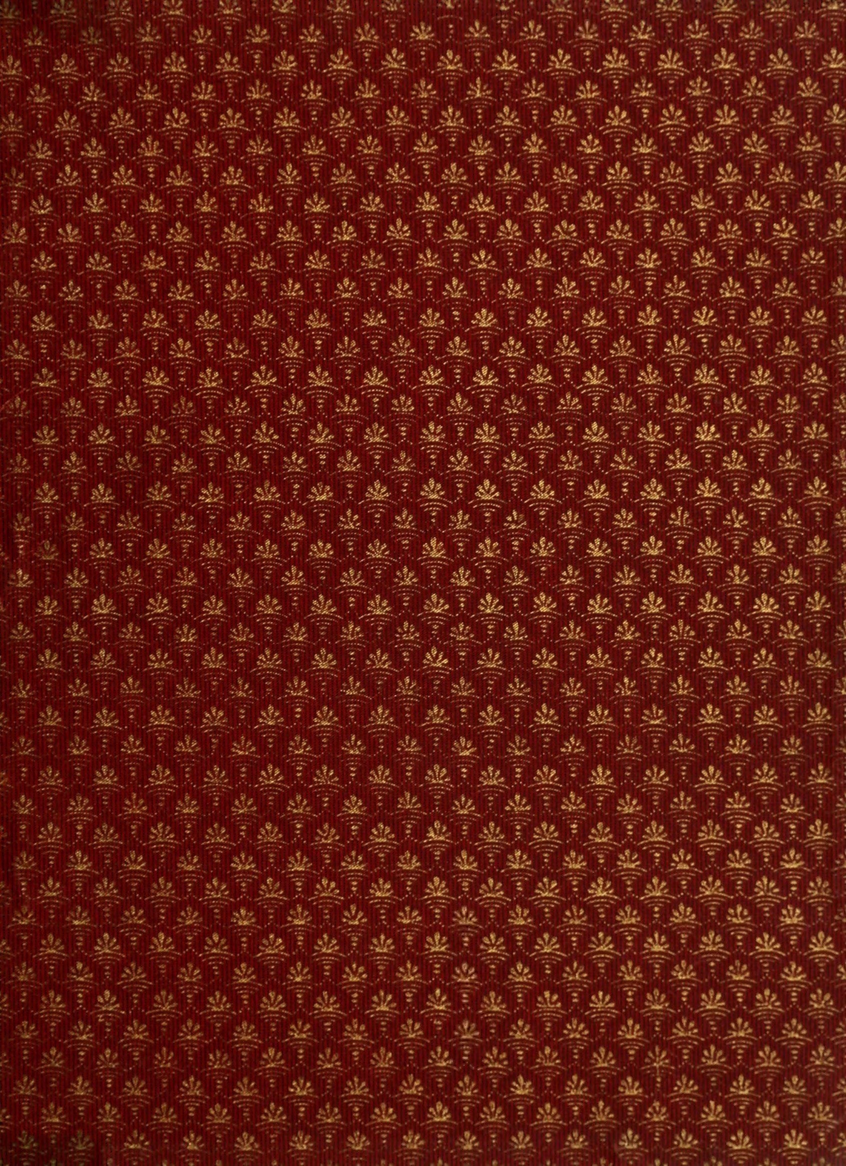
Likewise, [illegible] [illegible] phenomena [illegible], and the [illegible] [illegible] [illegible] the plate [illegible] [illegible] the [illegible] by the [illegible]. The ascending portion of its filaments.

It seems to me clear, that if the ascending limb of the filament, as seen in cross-sections, [illegible] detached in these species which closely connected to the former with plate [illegible], we ought to regard the plate as being homologous, not alone to the descending limb of a filament, as [illegible] believes, but to both descending and ascending limbs, as the latter is merely a continuation [illegible] from the end of the former.

Vita.

[illegible] born in [illegible], in the year [illegible]. In 18[illegible], I entered the Freshman Class of [illegible] College, [illegible], and in [illegible] received the degree of [illegible] from that institution.

In the fall of [illegible] I entered the Johns Hopkins [illegible] under the direction of Professors Brooks, Martin, Andrews and Howell. I have been assistant in [illegible] Fellow.

During the last two summers I have been on the staff of investigators of the United States Fish Commission, my work being done in the Commission laboratory at Woods Holl, Mass.